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ABSTRACT

Research to develop a fifth generation of computers is underway in several countries. These computers, which will be distinguished by the ability to provide knowledge information processing and respond to natural language commands, will have a profound impact on the labor market and hence on further education. Rather than being a separate curriculum area, computer studies should increasingly underlie the teaching and learning of each subject area, offering a knowledge-based approach to computer literacy. The role and form of face-to-face teaching must be reassessed, and institutional amalgamations may be necessary to meet the new perceived needs. Staff development must be focused both on using the expanded capabilities of the new computers and on addressing their social implications. Colleges should have information technology development units to develop pertinent curricula and materials, introduce artificial intelligence to teachers, and collaborate with subject specialist teachers in introducing the applications of advanced information technology into their subject areas. Company involvement in collaborative projects should also be encouraged. (Appendixes to this report include a glossary, selected quotations dealing with fifth generation computers and their likely impact, an introduction to micro-PROLOG and Augmented PROLOG for Expert Systems--APES--and an annotated bibliography.) (MN)

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FIFTH GENERATION COMPUTERS

Their implications for further education

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FURTHER EDUCATION UNIT

FIFTH GENERATION COMPUTERS

Their implications for further education

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FURTHER EDUCATION UNIT

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Press and other interested
Institutions/Individuals.

Dear Sir/Madam,

FIFTH GENERATION COMPUTERS: THEIR IMPLICATIONS FOR FURTHER EDUCATION

I enclose a copy of the above document by Richard Ennals and Arthur Cotterell. It discusses the possible implications for further education of the forthcoming fifth generation computers. It relates generally to the 1982 ALVEY Committee Report on Advanced Information Technology (AIT), but it particularly deals with the potential of the 'expert systems' that will emerge from this technology.

The AIT programme is well under way through collaborative projects involving industry, universities and polytechnics. But so far the implications for NAFE have been largely ignored. This document, by discussing issues of curricula, educational technology and organisation associated with FE, identifies problems that are already with us. The provision of the right type of work-force, the adjustment of learning strategies and the application to college organisation and management are typical issues that obviously require further attention.

Written in largely non-technical terms, this document should be valuable to FE managers and teachers. It provides a valuable introduction to a fast-moving field. A glossary of quotations and suggestions for further reading are provided for those who wish to extend their understanding.

A few simple messages come through. Teachers who maintain a clear understanding of their specialism, together with a willingness to apply today's computer technology to their subject, are more likely to cope with AIT. Teachers who are already aware of the potential of computers to learning strategies are less likely to be threatened by knowledge-based systems. Managers who already recognise that the concept of the electronic office applies as much to education as to industry are unlikely to be caught out by change.

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Implied by all this is the need to integrate the processes of staff, curriculum and management development. The Kingston IT Development Unit is described as a possible exemplar. The FEU has already held two oversubscribed conferences on this topic, and, with the MSC, have jointly sponsored a project at Kingston CFE, aimed at providing a 'starter-kit' related to expert systems. Those interested should contact Bill Congalton of the FEU.

In the meantime, it is hoped that this brief document will be a useful introduction to what must be an increasingly important development for all of us.

Yours faithfully.

Jack Mansell

JACK MANSELL
Chief Officer

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INTRODUCTION

The United Kingdom has set a lead in the introduction of microcomputers into schools. It has also set a lead in advanced computing research, and in particular in logic programming, that has contributed to the current development of a new fifth generation of computers. These new computers are very different from those being introduced into schools, and require a very different style of programming and use. As it becomes clearer what form the new computers are to take, this report seeks to examine the implications of fifth generation computers for further education.

In addition to this report, the authors are currently establishing an Information Technology Development Unit at Kingston College of Further Education, with the support of the Nuffield Foundation and collaboration from local companies.

The main body of the report attempts a non-technical account of fifth generation computers and their likely implications for further education. This account is supported by the appendices, which give an account of the role of an Information Techology Development Unit, a glossary of terms, and selected quotations from a variety of authorities on the subject of the report. A short introduction is given to micro-PROLOG, the language used for many of the examples in the report. Following references we have provided an annotated bibliography of useful books.

Richard Ennals
Arthur Cotterell

FIFTH GENERATION COMPUTERS

The Japanese Proposal

1. Since the first computers were produced following the Second World War, computer power has increased enormously but their size and cost have dramatically fallen. However, their design has remained fundamentally unchanged.

The first computers resulted from considerable research activity in cryptography and numerical analysis, with the earliest computer languages at binary and machine code level, reflecting the mode of operation of the machine. Successive languages have been progressively "higher level", reflecting more the way humans think and use languages, such as English. Computer applications, formerly dominated by "number crunching" in mathematics and science, have extended to a wide range of subject areas, particularly with the developing use of databases.

2. The computer world has been dominated by American companies, and in particular IBM. However, the Japanese Ministry for International Trade and Industry (MITI) decided to co-ordinate a Japanese challenge, and commissioned an extensive study of research and development prospects. The results were announced in 1981, with the revelation of the plan to produce "fifth generation computers", (further details are given in Appendix B.1). The concept of generation derives from the hardware, successively built of vacuum tubes, transistors, integrated circuits and large-scale integrated circuits, stages shown in figure 1. The new machines will be based on very large scale integration (VLSI) and involve several radical departures from conventional computer design.

3. Computers have always operated sequentially, with one central processing unit dealing with a sequence of instructions, known as a program. But fifth generation machines are highly parallel, with numerous processors working together. Traditional sequential programming languages will no longer be adequate, together with the concepts of computing which they embody. Accordingly, a new family of languages will be used, based on

logic programming and running on the parallel machines. Figure 2 summarises these developments.

4. At the user level these new machines will be very different from present day machines, where we "input" data using a "QWERTY" keyboard, and are normally obliged to use a particular computer language or notation. But it is proposed that in future we should be able to address the computer in our own natural language, or with graphics. Indeed, some microcomputers already accept some spoken commands, with others offering graphical features directed by a hand-held "mouse".

The user will be able to perform what the Japanese call "knowledge information processing", allowing computers to give advice on tasks such as repairing a car, making management decisions, translating from a foreign language. In fact, expert systems in America, from which many of the Japanese ideas were taken, have dealt with problems such as medical diagnosis and mineral exploration.

5. The expert systems are to be written in logic programming languages, for which the basis is PROLOG, with added facilities for knowledge representation. This represents both a departure from conventional computer science and software engineering where languages such as PASCAL, BASIC, etc. are used, as well as the dominant American artificial intelligence language LISP.

At the Fifth Generation Computer Systems Conference in Tokyo in November 1984, it was demonstrated that the ambitious research project is on schedule. PROLOG machines are running at ICOT (The Institute for New Generation Computing Research) with a new knowledge representation language, Mandala, and Concurrent PROLOG. Work continues in developing both the parallel machines and expert systems application, some of which were demonstrated. There is particular work on natural language understanding, using PROLOG, and on translation from spoken English to Japanese.

The International Response

7. The Japanese initiative has prompted research and development programmes around the world. In particular, it was

the Japanese invitation to collaborate that led in Britain to the setting up of the Alvey Committee by the then Minister of Information Technology, Kenneth Baker. In the United States, DARPA (Defence Advanced Research Project Agency) have an ambitious programme; IBM have greatly increased their activity in logic programming, and a number of major companies have combined their efforts in the MCC consortium. In Eastern Europe there is a Soviet-led Fifth Generation Programme, building on logic programming expertise in Hungary. New research centres are being established in Australia, Israel, France, Germany and Canada, as well as in China.

The Alvey Programme for Advanced Information Technology

8. In March 1983 Government approval was announced for the main recommendations of the Alvey Report, a £350 million national programme of research and development involving collaboration between the Department of Education and Science, the Department of Trade and Industry, the Ministry of Defence, academic research groups and British industrial and commercial companies, with companies paying half the costs of their involvement. The Alvey Directorate was set up to direct this programme.

The Alvey Programme is less focused than the Japanese Fifth Generation Programme. But the Alvey Directorate has identified the enabling techologies of:

- Man-machine Interface, dealing with the ways in which humans interact with computers

- Intelligent Knowledge-Based Systems (IKBS), the artificial intelligence part of the programme

- Software Engineering, including the development of languages and techniques of software

- Very Large Scale Integration (VLSI), the physics of small devices, their design and manufacture

A further initiative in 1984 has addressed Declarative Systems

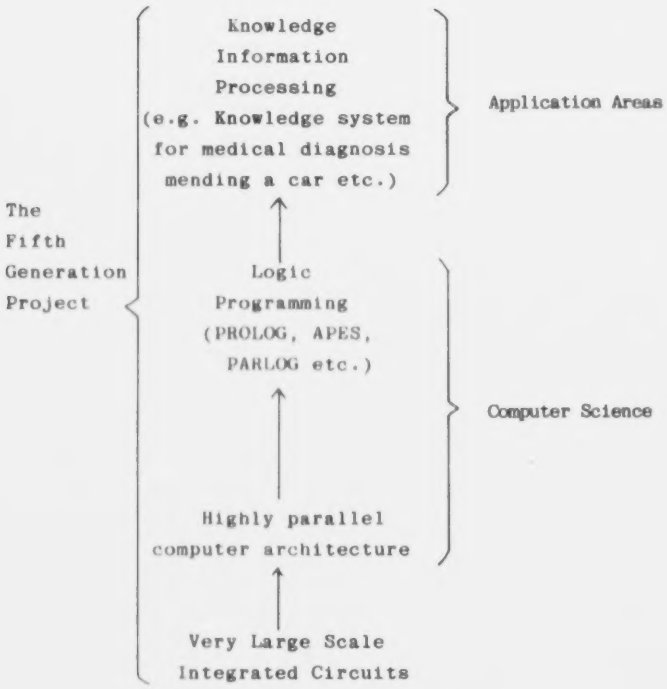
Figure 1.

Five Generations of Computer Technology

Generation	Electronic Component	Advantages	Disadvantages
1st generation 1940-52	Vacuum tubes	Vacuum tubes were the only electronic components available	Large size Generated heat Air-conditioning needed Unreliable Constant maintenance
2nd generation 1952-64	Transistors	Smaller size Less heat generated More reliable Faster	Air-conditioning required Maintenance
3rd generation 1964-71	Integrated circuits	Even smaller size Even lower heat generated Less power required Even more reliable Faster still	Initially, problems with manufacture
4th generation 1971-	Large-scale integrated circuits	No air-conditioning Minimal maintenance High component density Cheapest	In 1981 less powerful than than mainframe computers
5th generation		currently under development	

Figure 2

Logic Programming and the Fifth Generation



Architectures, supporting work on parallel computer architectures, logic programming and large databases. Declarative systems place emphasis on enabling the user to describe his problem, rather than being concerned with how to solve it.

9. The scope of the Alvey Programme can be illustrated by describing selected projects. These projects (termed demonstrator projects) have been chosen to exhibit and explore the potential of the enabling technologies.

* A desktop voice-driven computer is being developed on a large demonstrator project led by Plessey. Using the new ALICE parallel computer under development at Imperial College, and work in phonetics and linguistics at Edinburgh University, the company intend to produce a computer workstation that will, for example, take dictation for word processing.

* ICL lead a large demonstrator project with the Department of Health and Social Security and the Universities of Surrey and Lancaster, together with Imperial College. Expert systems are being developed to aid claimants and DHSS staff, and to aid in the interpretation of legislation and regulations.

* Numerical Algorithms Group Ltd. and the Departments of Computing and Mathematics at Imperial College are developing an "intelligent front end" to the GLIM statistical system, enabling wider range of users to make sure of its specialist facilities.

10. There is an increasing awareness that high-technology manpower is the key to the effective use of advanced information technology, and that failure to recognise this manpower need could be fatal for our national competitiveness. Alvey has responded with funds for supporting new information technology lectureships in universities, as well as research projects in numerous universities and companies. New distance learning courses are under development with the Open University, and the new IKBS Journeyman Scheme supports the secondment of experienced

people from industry to work for six-month spells in selected research centres, initially Imperial College London and the Turing Institute, Glasgow.

11. The research community remains small, and urgent measures are needed both to train researchers and to equip the wider community for the intelligent use of the new generation of technology. This is also an international problem, requiring new kinds of collaboration and institutional structures.

For further details see Appendix B.2

THE PROBLEM REGARDING FIFTH GENERATION COMPUTERS AND FURTHER EDUCATION

12. A first reaction to fifth generation computing is to view this development as an extension of present day computing. However, fifth generation computers ar not simply a development of present technology. They cannot be treated in the same way nor introduced with the same courses, languages, hardware and attitudes. We are obliged to explore new approaches for the following reasons:

* The speed of technological changes has exceeded the capacity of academic computer scientists to keep up. The problem is all the greater for college lecturers.

* Until recently there has not been available literature on which FE lecturers can draw for considered views on fifth generation computers.

* The research community in the UK, particularly in Intelligent Knowledge-Based Systems, although distinguished, is small in numbers.

* To date, Government plans in fifth generation computing or advanced information technology have given little place to Education and to Non-Advanced Further Education, in particular.

* Government has not regarded further education as its preferred instrument of technology transfer, and control is being increasingly passed to other agencies, such as Youth Training Schemes run by the Manpower Services Commission.

THE PROBLEMS POSED BY FIFTH GENERATION COMPUTERS FOR EDUCATION AND TRAINING.

The Manpower Crisis in the Information Technology Industries

13. The Alvey Report on Advanced Information Technology makes frequent mention of the manpower implications of work in advanced information technology, and of the need for an extensive programme of education and training at all levels. The Alvey Report and the Government regard British success in advanced information technology as essential for a sound economic future. However, Government cuts in education provision have reduced the number of computer science and other technology graduates since 1981. Indeed a succession of reports, including the Butcher Report and the NEDO Report, have identified a shortfall of several thousand high technology graduates per year. A group of high technology companies have responded by proposing the funding of a new information technology university at Milton Keynes, and possibly a further institution at Salford, using former university buildings.

14. Further, the need for high technology education applies at non-advanced and technician level if British industry is to have skilled manpower. Numbers employed in information technology in Britain have, in fact, fallen in recent years while the rival industries overseas have expanded. Whereas 152,000 jobs existed in 1970, by 1983 the number had dropped to 123,000. Many traditional apprenticeship schemes have closed and at the same time Britain has many more unqualified school-leavers than her industrial rivals with less provision for vocational training for all. Many industrial training boards have ceased activity while few high technology companies have accepted responsibility for the training of their employees, preferring to attract trained personnel from their rivals through the offer of higher salaries. They, in turn, lose many staff in the face of better financial offers from overseas and, in particular, the USA. This syndrome is persistent and increasingly powerful. Thus, there is a resulting manpower crisis in the information technology industries.

The Inappropriateness of Traditional Solutions

15. Traditional solutions for training problems in this new fifth generation computing field are inappropriate, for the provision of limited computer hardware without a coherent education or training methodology or strategy is placing considerable strains on the institutions concerned. Present provision also gives undue emphasis to hardware and to programming in BASIC, offering the student a limited and limiting impression of the power of the new technology. Indeed, the Alvey Report expressed concern about the spread of a low level understanding of BASIC due essentially to the wide availability of microcomputers;the report stated that the provision of hardware was not enough, for "teachers must be properly trained, and the languages taught chosen with an eye for the future" and college courses in computer science have of necessity been limited by the degree of understanding and experience of the lecturer. Indeed university departments of computer science prefer their undergraduates not to have taken such courses, seeking instead evidence of sound studies in traditional subjects, especially mathematics.

16. There has been an increasing divergence in the emphases of university computer science courses and the stated requirements in industry for short-term recruitment. Data processing departments still advertise for FORTRAN and COBOL programmers, while university courses emphasise languages such as PASCAL, ADA LISP and PROLOG.

17. Such divergence is a manifestation of a software crisis in computer science where the main cost of a large computer application is software development and maintenance. With large complex systems in defence or commerce, it is essential that systems should be reliable and comprehensible. For example, the recent problems in launching satellites from the American space shuttle have been attributed to a simple syntax error in a FORTRAN program, and the panic at the Three Mile Island nuclear power station was exacerbated by the computer system being unable to explain what was going wrong and resorting to cause lights to flash. So conventional programming has not proved adequate to the task, and the new approaches that are being developed

represent a radical departure from standard practice. New techniques of software engineering, of formal methods, of the use of fourth generation languages such as PASCAL etc. have so far had limited impact in college courses, where syllabuses can be slow to change. A similar situation exists in industrial training courses.

18. New techniques of fifth generation computing may have a limited impact in an educational and training environment that preserves an approach to the problem from previous decades. Experience suggests that the introduction of new ideas and techniques through traditional computer science courses may be less effective than adopting a "knowledge-based" approach, where the emphasis is on thinking about particular problems with the aid of the computer, enriching the teaching and learning of other subjects rather than perceiving computing as a separate, unrelated study.

FURTHER EDUCATION AND FIFTH GENERATION COMPUTERS

19. The possible impact of fifth generation computers in FE and, in particular, of expert systems can be described for each of the three areas identified in the FEU Policy Statement, A Framework for Action in IT, namely the curriculum, education technology and the management of learning, and the organisation and management of colleges. Expert systems, as developed in the last decade in American research laboratories, and now becoming increasingly widespread on microcomputers, have a number of distinguishing characteristics. They contain (i) knowledge concerning a particular subject, (ii) rules of inference so that the knowledge can be organised and manipulated, (iii) the means of users having a dialogue with the system using a form close to natural language, and (iv) the means of explaining the reasoning used in arriving at conclusions. Early examples, such as the first two cited in Appendix B.4, concerned medical diagnosis and mineral exploration. A great variety of areas, from the curriculum, through educational technology to college administration, are amenable to the application of such systems, as the example concerning legislation indicates.

It will be evident that the actual impact of the use of new computer technology in further education will be partly consequent on policy decisions yet to be taken, so we illustrate the possible impact with a series of examples, trying to make reference to areas of current FEU concern, as evidenced by sponsored projects.

Curriculum Issues

20. We envisage that, rather than computer studies being a separate curriculum area, the use of the technology should increasingly underlie the teaching and learning of each subject area, offering a knowledge-based approach to computer literacy. We draw the parallel with the initial stages of learning to read and write in primary schools, where the activities of reading and writing increasingly occur in the context of different subjects. Experience suggests that the initial familiarisation using advanced computing can be brief, if it is well presented. Furthermore, new microcomputers that are entering use in colleges

assume no past technical knowledge from the user, and present fewer obstacles to intelligent use than the previous generation of microcomputers whose use is now prevalent. Some examples are given below. Different viewpoints are presented in Appendix B.5.

Car Maintenance

21. Students need to gain familiarity with different vehicles and their maintenance problems. We are familiar with diagnostic checking equipment which gives a numerical and visual display of the results of electrical and mechanical tests. Students will use diagnostic fault-finding expert systems to help them identify the causes of vehicle malfunctioning. A conversational interaction will occur, using a keyboard, "mouse" device or voice communication, with the system providing advice and guidance to the student. The system can also simulate problems for the student to solve, including those that could be dangerous in workshop conditions, and monitor his progress.

Plumbing

22. Plumbing can be taught as a knowledge-based skill, enhanced with the assistance of advanced computing. We can envisage hand-held powerful computers used on the job, giving access to the databases of local suppliers, and to the records and plans of the local council and water board. Complex planning and design problems may be resolved by describing them to the computer. "How can I design this kitchen so that it contains a washing machine, a dishwasher and a sink, as well as radiators and a central heating boiler?" "Can the heating system that has been ordered support all those appliances?" "What modifications can be made to satisfy different constraints?"

We can envisage the plumber seeking the advice of an expert system, possibly based in the site hut. His problem might be the choice of appropriate pipes to meet the needs of the kitchen, and he may be restricted to a certain number of suppliers. The dialogue in the site hut could take the form :

Plumber: What pipes should I choose?

Computer: What appliances do you have and what do they take in?

Plumber: The sink, washing machine and dishwasher each take in cold and hot water. The boiler takes in cold water.
The cooker takes in gas.

Computer: What sources do you have and what do they give out?

Plumber: The water main gives out cold water. The boiler gives out hot water. The sink, washing machine and dishwasher give out waste water.

Computer: What does the sink work with?

Plumber: The water main and the boiler.

Computer: What dimension is the sink input?

Plumber: 1 inch.

Computer: What dimension is the water main output?

Plumber: 2 inches.

.....

Computer: 1 inch pipe and 2 inch pipe are available from Store B
1 inch to 2 inch converter is available from Store B

.....

Using a simple program the computer has solved some problems by obtaining information from the plumber, and others by checking the database of stock listed by local suppliers, from whom it could place an order at the end of the interaction. It can explain how it arrives at a conclusion. For example:

Plumber: Why do I need a 1 inch to 2 inch converter?

Computer: You need a 1 inch to 2 inch converter because you said that the sink takes in water and the water main gives out water.
In order to connect the sink with a dimension of 1 inch and the water main with a dimension of 2 inches I have suggested a 1 inch to 2 inch converter, which I know is available at Store B.

The plumber is not likely to want to type text on a keyboard. Rather, he should have the option of using a touch-sensitive screen, where he might touch the picture, or "icon" of

a sink, washing machine or other familiar part of the plumber's world instead of spelling it out. Such facilities are becoming available for microcomputers, and can be used for practicial purposes, especially for problems where the likely components to be fitted are known in advance. The computer is coming closer to the plumber's world, and could become as familiar a tool as a wrench. This has implications for FE as students can easily develop, modify and use systems to help with such problems and they will expect to see such techniques as part of their FE course. A fuller introduction is given in Appendix C.

Financial Modelling

23. Financial modelling is a concept with far broader applications than economics and business studies. Current research is developing "intelligent front end" interfaces to complex modelling systems, giving the non-specialist student access to economic and financial models, and the means of receiving explanations of answers given. A student may be asked to explore the impact of a change in the level of rates in the financial planning of the local authority, using a computer model of the borough finance department. He might want to ask what level of wage increase would produce the lowest rate of increase in unemployment according to the Treasury model of the economy, already open for public use on computers. Courses on developing a small business could use models taking account of cash flow problems, changes in personal and indirect taxation, as well as non-numerical factors such as employment legislation.

Design

24. New computer systems are making increasing use of graphics, and graphically-based operating systems. Using the hand-held "mouse", the designer can select from different "icons" displayed on the screen, and can develop complex designs. Different "windows" can be opened on the screen to give "painting" or "editing" facilities, and the final design can be printed out. Photographs and maps can be displayed and incorporated. If a tool or system is being designed, the computer can be so programmed that the design can be used as a model of the system, performing some of the functions in simulation.

History, Humanities and Social Science

25. Computer usage needs no longer to be based on a numerically-oriented view of computers. Historians and social scientists need to ask questions, to explore complex bodies of knowledge and to understand the actions and belief systems of others. Local and national records are increasingly available in computer form. Understanding a complex situation is often made easier by developing a model or simulation. Historical and social scientific research projects can be enhanced by the classroom use of the computer. For example, students of nineteenth century history may make use of the local trade directories and census returns in the form of databases, enabling them to explore historical issues in greater depth. Progressively computer use will not require knowledge of computer languages but the ability to express oneself clearly in natural language.

Languages

26. Considerable research has been devoted to natural language understanding and translation using the computer. Systems available to colleges will cope with defined subject areas where the vocabulary is known and sentence structures are not too complex. Such systems are also likely to be powerful teaching tools, showing how grammatical rules work in practice, and demystifying some linguistic concepts that are not explained in courses today. Language systems could be used in both written and oral work, and could be developed by the student.

Electronic Office

27. We are approaching the time when issues of the electronic office, as of computer studies/literacy, may be subsumed in the teaching of other subjects. Already many American colleges require their students to have a computer, which is used for word processing and electronic mail as well as for programming and the running of applications. Such courses may initially become more "experience-centred", allowing the working of an office to be explored in more depth. Changing hierarchies in modern electronic offices must be reflected in courses in further education.

Science

28. Considerable use has already been made of computers in some science courses and we can here explore the enhancements to be expected from fifth generation computers. Non-numerical knowledge will have greater attention, with students manipulating, experimenting with and interrogating knowledge structures. For each rule or connection there will be a corresponding explanation available to the student. A complex piece of reasoning can be traced and examined. Models can be tested. Large databases can be consulted, and pilot expert systems constructed to organise and explain problems in science. What conclusions can be drawn fom the periodic table of the elements? How is chemical nomenclature arrived at? How do we measure the age of archaeological finds? How can we develop our own taxonomy for plants or insects? What threats to the environment could be posed by fertilisers, chemical plants, or conversion of marshes to agricultural use?

Engineering

29. It is likely that engineering courses will pay increasing attention to formal thinking. Clear descriptions will lead to a design for a product or a program for a robot or control device. Ideas of expert systems will be used in application areas such as water control and vehicle monitoring. Already the discipline of software engineering is influential, with a corresponding growth of engineering software. Further, the distinction between hardware and software is likely to become less significant with students building devices incorporating microprocessors with software or VLSI programs. For example, robots and robot arms will be used with other more conventional machine tools providing a significant extension of current college work in CNC and CAD/CAM. The new field of Computer Integrated Manufacture (CIM) is developing the use of advanced information technology throughout manufacturing industry.

Information Technology

30. Information technology in itself affects the nature of what is taught, as well as methods of teaching. We have yet to see

the educational effects of college-wide networks with electronic mail, bulletin boards for interest groups, and communication with computer systems around the world. Just as styles of writing have been affected by the advent of word processors, styles of research and communication will change with computer networks. Electronic reference sources will take over some of the current roles of the books in the college library, and may enable students to pursue their studies in greater depth. In some sense, as McLuhan wrote, "The Medium is the Message". There is a growing case for courses in the implications of information technology, possibly as an extension to current courses in communication and media studies.

Overall Issues

31. There is likely to be a challenge to conventional curriculum subjects, in that teaching will have to reflect technological advances with emphasis on clear logical thinking, and on personal study skills. The computer may facilitate a more individual approach to learning by the student, and a more knowledge-based approach to teaching by the lecturer with a greater and more thorough use of library facilities, where material will be stored on magnetic media and videodisc as well as in books. Appendix B.6 gives different views on computers and education.

Educational Technology

32. As computing becomes an increasingly universal technology, it will also change its role in educational technology. The computer will lead to more flexibility in educational technology and the result will be a system more responsive to the needs of the individual.

Our analysis draws on the work of Pickup and Cameron on the FEU Project "Computer-based Educational Consultancy",* at Garnett College. The work was concerned with applying artificial intelligence techniques in creating microcomputer software to

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* Computer-Based Educational Consultancy FEU Research Project 141 Formerly at Garnett now at Kingston CFE.

assist teachers in course planning. Traditionally the methodologies and expertise employed tended to be informal or ad hoc, and therefore not readily specifiable as a "knowledge base".

Current requirements, however, are reversing this pattern and an increasing burden is being placed on course planners to specify their intentions in detail, often in the terms of complex schemes. Computer software, which assists openly and intelligently in this activity, should not only serve as a productivity aid but also enhance the lecturer's own conception of the task in hand. Indeed, an important additional application for such software will be in context of teacher training.

Pickup and Cameron have developed a program for (i) categorising educational objectives, (ii) checking a course against complex requirements and recommendations, and (iii) selecting teaching strategies using decision-making principles described in three different forms.

33. However, a particular problem identified by Pickup and Cameron, in common with other researchers, is that of knowledge acquisition - the problem of transferring expertise from the human expert to the machine. The work at Garnett College has explored the use of decision nets and, using specific examples, demonstrates the selection of appropriate methods for teaching a particular subject. More advanced techniques are being investigated at the Turing Institute in Scotland, with some impressive results, where expert systems are designed to inductively learn new rules for classification or for chess-playing.

34. The same technology that is being used to advise lecturers could, of course, advise students : on what courses to take; on which teaching method (given a choice of learning) they will find most useful; on how to plan their work.

Similarly "education consultants" could offer careers guidance and welfare rights information. In each case the text of the knowledge base should be accessible and comprehensible, and explanations should be provided for information given.

35. In general,educational technology is presented here as helping to make knowledge openly available. Elsewhere we are likely to see the use of the technology for purposes of persuasion, with the user denied free access and explanations. It may be, in a manner reminiscent of Vance Packard's The Hidden Persuaders, that by making open use of the technology in education we can help expose its dishonest and partial use elsewhere. There has been a tradition of work in "Intelligent Computer-Assisted Instruction" and "Intelligent Tutoring systems". More powerful low-cost computers and programming techniques are bringing such systems within reach of college budgets, and should increasingly incorporate the results of artificial intelligence research.

Organisation and Management

36. For many years organisations have been described in "systems" terms, and methods of management have been applied that derived from past generations computing research. We have the example today of the organisation of ICOT (Institute for New Generation Technology) in Tokyo, adapted to the management of the problem areas and methods of advanced technology. The British Alvey Programme is likewise forcing new methods of organisation and management to meet the needs of collaboration between academia and industry. Appendix B.7 suggests some implications of new technology for the workforce.

37. In further education there are likely to be changes in organisation and management as a result of fifth generation computing that extend beyond the computer as a management tool. The very existence of the colleges may be called into question with the spread of powerful computing facilities in the home. There may be a radical reassessment of the role and form of face-to-face teaching, and institutional amalgamations may be necessary to meet the new perceived needs. Further companies may decide to increase massively their own computer-aided training in-house, and place correspondingly fewer demands on the college.

38. Within colleges some new concepts may have an impact on organisation and management. Discussion of problem solving by

"top down" and "bottom up" strategies, emphasis on clear description and specification, development of explanation facilities and "user friendly" interfaces, concern for structure, modular development and methods of debugging - all directly relate to organisation and management. The presence of students and lecturers with expertise in the "electronic office" should motivate administrators to apply the new techniques to their own institutions, drawing on the experience of participative democratic systems design in Scandinavia and the work of Professor Mumford in Britain.

Staff Development

39. Of central importance is the provision of staff development that responds to differing staff reactions to new technology. Our experience to date indicates that the staff who take most willingly to expert systems are those with a clear perception of their own specialist area, a scepticism of conventional computing and a reluctance to compromise academic principles for a machine. On the other hand the greatest resistance has been shown by those with the involvement with conventional computing, often at the expense of a concern for traditional subjects.

40. Colleges will have to assign significant periods of time for ongoing staff development, both in-house and in consultation with local companies and research centres, which could involve exchanges and secondments. Staff development should be based on the following core areas of IT and expert systems where the aim is to familiarise the learner with the following ideas :

concepts of knowledge, and information leading to procedural and declarative thinking. LOGO and conventional programming languages would be involved in the area dealing with procedural thinking with PROLOG involved in declarative thinking. Important applications areas such as information handling (databases and spreadsheets) and word processing would be included. An introduction to expert systems would demonstrate how the knowledge structures of the 'expert' are held in the computer and how such systems are put to use. Finally the social implications (i.e. the effects on leisure and working activities) for all these areas would be taken into account.

The basic elements of a formal staff development programme should therefore include areas such as:

- Concepts of knowledge and information;
- Procedural thinking in LOGO and conventional programming;
- Declarative thinking with logic and PROLOG;
- Information handling: databases and spreadsheets;
- Word processing;
- Introduction to expert systems;
- Social implications.

An important dimension for staff training would be the applications of each of these IT areas in the subject areas of individual members of staff. In addition to the specialist skills and knowledge associated with each of these areas, staff would have to analyse their subject area to prepare a curriculum showing how these areas of IT relate to topics within their subject. More specifically, the participants should be able to :

* describe and model some of the learning problems of their students;
* describe in general terms how such descriptions or models can be handled by a computer;
* identify different approaches to knowledge representation related to particular learning problems;
* evaluate the possibilities of artificial intelligence ideas and tools as a possible solution to given learning problems;
* plan in co-operation with appropriate colleagues, the implementation of a learning activity incorporating artificial intelligence techniques;
* construct an effective learning activity incorporating artificial intelligence ideas and tools.

See Appendix E for an annotated bibliography of relevant texts. Resources must be provided to allow for individual study with a computer. These teacher-centred activities should be supported by lectures and wider presentations, but successful staff development is as much based upon participative learning,

appraisal, visits and real curriculum development - as it is on formal sessions.

41. Staff development must relate to a number of organisational and management tasks that can now be performed (although taking into account the Data Protection legislation). Some examples of these tasks are :

- the use of large relation databases used for records and profiles, with retrieval - using writing packages if desired;
- timetable constructing with its reasoning in terms of rules made clear is a classic example for potential application of the computer, although at present heads of departments unaided can outdo the computer; increasingly complex tasks of budgeting and costing external courses can be done;
- with an intelligent spreadsheet system, allowing automatic preparation of reports for governing bodies and local education authorities. Policy models can be developed, refined and tested before implementation.

A central problem of organisation and management in colleges is identifying the people for whom the computer can be used to solve rather than exacerbate problems, in management and interpersonal relations. The computer is a tool and not an end in itself. A college principal may want an "intelligent workstation" on his desk, to increase communications with colleagues and sources of information, but the management of the college will not necessarily be improved by linking all lecturers to a network.*

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* Information Technology and Computer Based Management (RP283) K Dean FEU.

POLICY RECOMMENDATIONS FOR FURTHER EDUCATION

42. Further education should not be seen in isolation from more general problems and from the activities of other education and training bodies.

43. Consideration should be given at Ministry level to policy initiatives in further education, in consultation with the Department of Trade and Industry and the Department of Employment.

44. The following policy recommendations are made:

* There should be a DES national conference on implications of fifth generation computers for further education

* There should be an IKBS Education and Training Journeyman Scheme whereby lecturers are seconded from further education to work in advanced research centres for periods of 6 months

* Video and text materials should be prepared for use in staff awareness courses in colleges, together with software.

* Colleges should be encouranged to establish Information Technology Development Units.

* College units should collaborate with each other and with subject specialists in developing applications courseware

* Company involvement should be encouraged in collaborative projects

* FEU and further education colleges should seek involvement in ESRC and Alvey Programme Initiatives in the Educational Implications of Fifth Generation Computers.

THE ROLE OF AN INFORMATION TECHNOLOGY DEVELOPMENT UNIT

45. An Information Technology Unit in a college of further education should be the focus of a number of interrelated activities in staff development.

I. The development and teaching of a core course in concepts of advanced information technology and expert systems to be offered to all students.

II. The development of modules incorporating applications of advanced information technology as components of the range of college courses.

III. Introducing artificial intelligence to teachers.

IV. Collaborating with subject specialist teachers in the introduction of applications of advanced information technology into the teaching of their courses.

46. The central purpose of the unit should be technology transfer, from the few with specialist expertise to the many who can make use of it. It will require computer hardware with sufficient power to run small expert systems; the same microcomputers that are now in commercial use. The management structure and system of accountability will vary between colleges, but the Information Technology Development Unit should not be identified with mathematics, science, or even computing, but involve representatives of each college department.

47. A college-based unit should enjoy the support of the Further Education Unit New Technology Working Group at a national level, and should establish connections with research groups and centres in their geographical vicinity, whether based in universities, polytechnics or industry.

Extending the Core

48. There is considerable potential for building on the core course for students and the introductory course for lecturers by progressively developing modules incorporating applications of

advanced information technology as components of specialist courses.

Some materials will have to be developed by the college unit with staff from the appropriate departments, some may become available from outside sources including other colleges, and some may be produced by adapting existing software systems for tutorial use. For example, intelligent front end programs can be developed for large software systems making them more accessible to the non-specialist user.

49. The expertise of the subject specialist lecturer is of central importance in the educational developments of expert systems and other forms of advanced information technology. Systems that are developed must meet the criteria of the expert, and should involve him in the development where possible. Staff of the Information Technology Development Unit take on the role of "knowledge engineer", seeking to represent the knowledge of the subject area in a way that satisfies the expert and provides appropriate answers and explanations in response to questions.

The lesson of previous collaborative research projects in this field is that this is the crucial stage in "technology transfer", where the new technology is taken on by the expert teacher or lecturer without sacrificing his view of his subject. The resulting programs and educational activity will vary greatly according to the background and educational approaches of the lecturers. The same program should be capable of use in a variety of ways.

APPENDIX A
GLOSSARY OF TERMS

ADA An advanced programming language being developed under the control of the American Department of Defence, named after Ada Lovelace, mistress of Charles Babbage (the inventor of the "Difference Engine") and regarded as the first programmer.

Advanced Information Technology (AIT) The term used in the Alvey Report and the Alvey Programme of Research to describe work in the fields of

Man-Machine Interface Intelligent Knowledge Based Systems
Software Engineering
Very Large Scale Integration

ALICE ALICE (Applicative Language Idealised Computing Engine) is a highly parallel computer under development at Imperial College by a team led by John Darlington. The first version is made of transputers.

ALVEY John Alvey of British Telecom chaired the committee which advised the British Government on its response to the Japanese Fifth Generation Initiative. The Alvey Programme for Advanced Information Technology started in 1983.

Artificial Intelligence (AI) The study of intelligence in thought and action. Computers are its tools, because theories are expressed as computer programs that enable machines to do things that would require intelligence if done by people. (See Appendix C)

BASIC An interactive language developed at Dartmouth College, USA in the 1960s to introduce novices to computers. It is available on different dialects on most microcomputers.

COMAL A language developed by Borge Christenson

for education use, based on BASIC but adding elements of structured programming deriving from PASCAL.

compiler The price of software which translates a whole program into the machine code which the computer understands. Compiled languages usually run much faster than interpreted languages.

database A collection of information stored on a computer. More recently the term knowledge base has been introduced, particularly where knowledge is shared, as in PROLOG, in facts and rules. Databases are interrogated using a query language. Recently relational databases have gained in popularity, offering more flexibile access to information. Logic databases using PROLOG can be seen as relational databases.

ESPRIT The European Community Research and Development Programme in Advanced Information Technology.

Expert Systems First developed in the United States, and written in languages such as LISP and PROLOG, expert systems have been used in medical diagnosis, mineral prospecting, and areas of legislation. (see Appendix C for example rules).

intelligent front end A program which gives the user the means of making intelligent use of a complex software system, such as statistical model or a large relational database.

Intelligent Knowledge-Based Systems (IKBS) This is the term used in the Alvey Programme to cover work in databases, expert systems, inference and natural language understanding.

interpreter The piece of software which translates sentences of a computer language into the machine code which the computer understands. Languages which are used interactively usually have intepreters.

LISP Since 1961, LISP (List Processing Language), developed by John McCarthy, has been the principal AI programming language in the United States.

LOGO LOGO is a dialect of LISP, developed for educational use following the ideas of Seymour Papert. The best known area of application has been turtle graphics. It is a powerful tool for introducting procedural thinking and concepts of structured programming.

Man-Machine Interface (MMI) Considerable work is being carried out on improving ways in which users can interact with computers; this includes the use of graphics, iconic systems using a hand-held "mouse", and the use of natural language.

micro-PROLOG micro-PROLOG is an implementation of PROLOG for microcomputers. Since 1980 it has been used for the project "Logic as a Computer Language for Children" based at Imperial College, as well as for research on expert systems, databases and man-machine-interface. See Appendix D.

mouse A hand-held device by which the computer can be controlled, instead of using the "QWERTY" keyboard. Mice are used with the Apple LISA and Macintosh, and with other advanced systems.

OCCAM The language developed by David May of INMOS to program transputers working together.

Parallel computers A computer with several processors working at once to solve a problem. ALICE is a leading example.

PASCAL A language, emphasising concepts of structured programming developed by Nikolas Wirth for educational use.

POPLOG POPLOG is a system developed at Sussex University, which offers facilities for programming in POP, PROLOG and LISP.

PROLOG PROLOG (PROgramming in LOGic) was first implemented in Marseilles in 1972 by Alain Colmerauer and his group. The theory of logic programming is due to Robert Kowalski, now of Imperial College. PROLOG was adopted by the Japanese as the starting point for their Fifth Generation Computer Project.

Software Engineering The discipline of producing reliable software which can be maintained and modified, and particularly concerned with problems of large systems.

Spreadsheet The term used to describe accounts packages that allow the user to make projections of financial outcomes on a "What if" basis, aiding in financial planning.

transputer The computer on a chip, developed by INMOS, and the building block for a number of new "computer architectures".

windows A facility whereby the screen can be divided into different sections to be used for different purposes, such as monitoring different processes or displaying information in different ways. Windows are often controlled with a hand-held mouse.

APPENDIX B

SELECTED QUOTATIONS

1. The Japanese Fifth Generation project

Social Objectiveness

'1. To increase productivity in low-productivity areas, for example, agriculture and fishing

2. To meet international competition and contribute towards international co-operation, for example "to cultivate information itself as a new resource"

3. To assist in saving energy and resources

4. To cope with an ageing society'

(Moto-Oka 1983)

Requirements of Computers

'1. They must be easier to use

2. There should be less burden of software generation

3. There must be improved reliability and cost performance'

(Moto-Oka 1983)

Previous Generation of Computers

'The changes from one generation to the next in computer technology have so far been made to accommodate changes in device technology, that is from vacuum tubes to transistors, then integrated circuits and recently to large-scale integrated circuits. Such hindsight tells us, then, that there have been no major changes in the basic

design philosophy and utilisation objectives of computers.'

(ICOT 1982)

Changes for the Fifth Generation

'With Fifth Generation computers, however, the expected generational changes is more like a "generic change" which involves not only a change in device technology, to very large scale integrated (VLSI) circuits, but also simultaneous changes in design philosophy and in fields of applications.'

'A new approach to the use of computers in proposed for a number of applied fields in the 1990s, involving a change from machines centred around numerical computations to machines that can "assess the meaning of information and understand the problems to be solved".'

'To accomplish this change a number of developments are required:

1. To realise basic mechanisms for inference, association and learning in hardware and make them the core functions of the Fifth Generation Computers.

2. To prepare basic artificial intelligence software to fully utilise the above functions.

3. To take advantages of pattern recognition and artificial intelligence research achievements and realise man-machine interfaces that are natural to man.

4. To realise support systems for resolving the "software crisis" and enhancing software production.'

(ICOT 1982)

Central role of logic programming

PROLOG (PROgramming in LOGic) seems to be the best suited as the starting point in considering new base languages for knowledge information processing .... while the route to knowledge information processing is an advance to a new age, it can also be viewed as representing the inheritance and development of the legacies of the past from the viewpoint of research efforts.

(Fuchi 1981)

Natural Communication with the Computer

The intelligent interface function will have to be capable of handling communication with the computer in natural languages, speech, graphics and picture images so that information can be exchanged in ways natural to man. As natural language processing provides the basis for translation, English and other languages are to be included as well as Japanese in the objects for processing. Ultimately, the system will cover a basic vocabulary (excluding specialist terms) of up to 10,000 words and up to 2,000 grammatical rules, with a 99% accuracy in syntactic analysis.

(ICOT 1982)

2. The Alvey Report on Advanced Information Technology

Section 7. 7.9 on Schools

Action must start in the schools. We support the moves which are now putting computing on the curriculum. But it is no good just providing schools with microcomputers. This will merely produce a generation of remedial education to entrants with "A" level computer science. Teachers must be properly trained, and the languages chosen with an eye to the future. Uncorrected, the explosion in home computing with its 1950s and 1960s programming style will make this problem even worse.

3. Overviews of Artificial Intelligence

Margaret Boden wrote (Boden 1977)

> 'Artificial Intelligence is not the study of computers, but of intelligence in thought and action. Computers are its tools, because its theories are expressed as computer programs that enable machines to do things that would require intelligence if done by people.'

Tim O'Shea and John Self (O'Shea and Self 1983) describe artificial intelligence programs as involving:

'1. remembering and assessing relevant knowledge;

2. using this knowledge appropriately, for example, to reason and to form plans of action;

3. revising and extending their knowlege;

4. searching in some more or less systematic way for a solution to a problem;

5. recognising similarities and drawing analogies between things;

6. attempting to understand some aspect of their surroundings, for example something communicated to them in English.'

4. Example Rules from Expert Systems

1. The MYCIN System (Medical Diagnosis)

(Shortlife 1978)

IF

1. the site of the culture is blood,
   and
2. the identity of the organism is not known with certainty,
   and

3. the stain of the organism is gramneg,
and
4. the morphology of the organism is rod,
and
5. the patient gas been seriously burned

THEN: there is weakly suggestive evidence (0.4) that the indentity of the organism in pseudomonas.

2. The PROSPECTOR System (mineral Exploration)
(Dude et al 1980)

IF: there is hornblende pervasively altered to biotite
THEN: there is strong evidence (320, 0.001) for potassic zone alteration.

3. Medical Treatment using APES (Hammond 1984)

x should take y if x has complaint z and
y suppresses z and not
y unsuitable for x

4. The British Nationality Act using APES
(Cory et al 1984)

x acquires British citizenship by l.l.a on date y
if x was born in the UK and
x was born on date y and
y is after commencement and
z is a parent of x and
z is a British citizen
by w on date y

5. The Controversy over the Impact of Fifth Generation Computers
Shirley Williams

'As so-called "expert systems" are adopted in new areas - medicine, the law, energy, economic policy for example, as well as defence - it becomes crucial that conclusions and assumptions embodied in computer software are able to be questioned: otherwise the choice of the expert will determine the outcome of the argument....'

'Society has a choice before it. It can use computer systems to centralise control, to widen the gaps between experts and lay-people, the information-rich and the information-poor, and to limit access to data to an educated elite, and a new priesthood of programmers. Britain, with its obsessive and extensive official secrecy, its inadequate training for new skills, and its increasingly centralised administration, could use computer systems in a way that damaged democracy.'

(Williams 1984)

Robert Kowalski

'It is all too easy to let computers take over. It is all to easy to let the computer decide. We've done it before. We do it with humans, with processional advisors, "let the doctor tell me what to do", "let the accountant decide how to run my financial affairs". The human expert can intimidate us by knowing more than we do and by having greater expertise. If humans can do that with humans, then computers will be able to do that with humans too; and they will do it, if we allow the enthusiastic technologist to have his way.

'The new rule-based, logic-based languages allow us to get rid of the "take it or leave it" attitude of computers today. They make it possible for computers to explain their conclusions, and, therefore, easier for us to decide for ourselves whether to accept their conclusions.'

(Kowalski 1984)

Malcolm Peltu

'Technology is not neutral. Its application reflects the values implicit in the prevailing power structures and the influences which shape society.'

'A special contribution of IKBS as an educational tool is its ability to make knowlege explicit so that the expert

program can become a teaching guide to a student, the automated equivalent of "sitting at the feet of the master.'

(Peltu 1984)

Margaret Boden

'Current expert systems are very limited in what they can do, largely because they cannot reason about their own reasoning - or the user's reasoning either. They cannot explain their conclusion differently to different people, since they have no user model in terms of which to adjust their explanations to the human's particular range and level of knowledge.'

'The average person must be brought to realize the limitations of programs as well as their potential. In particular, they must be alerted to the fact that every program can, in principle, be questioned.'

'Natural sciences like physics and chemistry are dangerous for two reasons. They can be misused by human beings for inhuman ends - as artificial intelligence can too, of course. In addition, they can insidiously lead people to mistrust those aspects of our minds that cannot be expressed in their terms. This includes all those psychological features, whether of action or experience, which we normally value in ourselves and our fellows.'

(Boden 1984)

Ian Lloyd MP, quoting Bertrand de Jouvenel

'Nothing is more dangerous for psychological eqilibrium that the launching of heady promises incapable of implementation. It is one of the tasks of those who envisage the future to zone off the unattainable. Many pleasing prospects are irreconcilable with human behaviour; the sociologist and the political scientist must here weed out the improbable, just as the economist must cut, in view of their investment costs, some of the technological forecaster's visions.'

Quoting Mort Sahl

'We have found the enemy and he is us.'

(Lloyd 1983)

6. Microcomputers and Education

Morley Sage and David Smith

'New technology is seen as offering teachers principal tools for the design and organisation of learning experiences, as well as providing a source of conceptual models of the processor and strategies of learning.'

'The main focus of attention in the Alvey report was on technological developments, and although attention was directed towards the understanding of cognitive processes and the organisation of knowledge for the design of expert systems, relatively little attention was given to the enormous potential value of this understanding for the evolution of education.'

'Education and educational services should be regarded as knowledge-based services with potentially world-wide markets, and the role for IT-based materials within this market is obviously likely to be very great.'

(Sage and Smith 1983)

Peter Goodyear

'Our thinking about the potential for exploiting technology runs way behind that technology's development. We should be thinking now about what education will need to be like in a computer-rich society. Yet everywhere are signs that our thinking about the nature of the computer, and its place in education, are ossifying.'

'How can we begin to think about the sorts of questioning, hypothesis forming investigative research skills that

learning with the Japanese computers might involve?'

(Peter Goodyear 1984)

Philip Virgo

'Our current education system is "schooled" into subject areas, while life is not. The ability of the expert system to manage complexity makes it ideal for controlling multidisciplinary study projects, crossing subject boundaries in a way which few teachers have the ability or knowledge to match.'

'We are failing because we expect to. We do not suffer from a lack of resources but from the fragmentation of those we have, the refusal to consider solutions we do not invent for ourselves, bureaucratic procedures and institutions which do not believe they can cope with change, an idiosyncratic examination system which reinforces the status quo and recruiters who have, for all too human reasons, given up trying to influence the systems they have to work with.'

(Virgo 1983)

Geoffrey Pattie MP

'I've always felt that getting the hardware into schools, though pretty fundamental (you can't teach piano leassons without a piano) is only one aspect. There are many others almost as important, such as making sure that teacher training is as good as it should be.'

'Technology "not as a subject in its own right, but as a means to actually solving problems throughout the school"'

'The more we make the curriculum as relevant as we possibly can through liaison with industry, companies and other means, the better.'

(TES 3.11.1984)

Igor Aleksander

'It is important to realise every effort is needed not only at the level of producing bigger and better machines and the manpower that implies. It has been argued that the roots of the problem are societal which require attitudinal rather than financial remedies.'

'Teaching people to make current computer structures and to program them when the research community is endeavouring to alter such structures out of recognition and to replace programming by more "natural" means of communication (speech, vision, natural language) seem sheer lunacy.'

'Teachers should be encouraged to make intelligent computer software available to pupils as a natural part of lessons rather than seeing computing as a separate, somewhat bewildering new topic.'

(Guardian 12.9.1984)

7. New Technology and the Workforce

Norbert Wiener

'Let us remember that the automatic machine ... is the precise economic equivalent of slave labour. Any labour which competes with slave labour must accept the economic conditions of slave labour. It is perfectly clear that this will produce an unemployment situation, in comparison with which ... the depression of the thirties will seem a pleasant joke.'

(Wiener 1950)

Royal Society of Arts

'If care is not taken, the result could be to degrade the job content and reduce job satisfaction. Employees might become disenchanted and bored with their work, leading to

social isolation and psychological stress.'

(RSA 1980)

J. Diebold

'One of the impediments to rethinking of products and processes has been that the traditional division of responsibilities has the effect of localising the areas in which rethinking is done. Almost by definition, however, rethinking must be done on an extremely broad basis - viewing the objections of the entire organisation as a whole.'

(Diebold 1952)

The Finniston Report

'The work of engineers "has direct and indirect effects on the tasks of other workers in the enterprise, the jobs and systems of which those tasks form a part and the total organisation of work. Engineers must, therefore, be concerned not merely with technically optimal solutions and systems but with the human and organisational factors involved in the operation of the system.'

(Finniston 1980)

The Trade Union Congress

'Trade Unionists need to take a great interest not only in the computer equipment - the hardware - but also in the software - the programs that control the information system. Who will write the programs? What jobs will the programs do? What say will the employees have in the way the programs work?'

(TUC 1981)

Ernest Bevin

'Society has made amazing progress, but society has not kept pace with it in making the fundamental readjustments, and assimilating the results of research discovery and invention. There is not only a "time lag" but the inertia and rigidity of our social and economic structure to be overcome.'

(Bevin 1937)

Philip Virgo

'We can no longer afford to spend one or two decades of detailed preparation for a single life-long career progression. Instead we should aim, like our ancestors, to impart those basic skills almost certain to be in continuous demand and to build a system capable of responding rapidly to change and disseminating new skills to any age group when necessary.'

'Rather than develop the learning skills of the few, we must train those of the many so that they can use the artificial intelligence and memory aids that will be available for all. Thus machines will take over the menial logic and memory tasks, leaving us humans with the interesting problems of judgment and the many inter-personal and service tasks which they may aid but cannot take over.'

'The handloom weavers' modern counterparts could well be the commercial programmers and analysts of today. Called into existence by the availability of expensive computers which had to be used efficiently, they may well be reluctant or unable to change trades when packaged software on cheap computers has made their particular branch of computing skills redundant.'

(Virgo 1983)

Sir Ieuan Maddock

'The reality of the learning curve has long been acknowledged in the planning and the execution of very complex projects ... But what of the forgetting curves - the ability to shed old outmoded techniques and attitudes, to surrender treasured traditions or to change employment in order to be competitive in a new field? .... It is not the inability to note and to learn the new techniques that leads to failure but the unwillingness to abandon long established methods and product lines.'

(Maddock 1983)

APPENDIX C

INTRODUCTION TO micro-PROLOG AND APES

micro-PROLOG has been implemented for a wide range of microcomputers, such as the Sinclair Spectrum, BBC micro, Commodore 64, Research Machines 380Z 480Z and Nimbus, all microcomputers with CP/M (or similar) operating system, and microcomputers with the MSDOS or PCDOS operating system, such as the IBM PC and ACT Apricot. A more powerful version of the language, Sigma-PROLOG, is available for computers with the Unix operating system such as the VAX, GEC-64, Fortune, Cifer, Perar and Sun. From the user's point of view it does not matter which computer is used, though for large programs it is helpful to choose a computer with a large memory.

APES (Augmented PROLOG for Expert Systems) is a program, written in micro-PROLOG, which provides additional facilities for the user, such as explanations and a conversational style of interaction.

Between them, micro-PROLOG and APES offer an introduction to ideas of fifth generation computing on microcomputers of 128K memory and above. Smaller microcomputers cannot hold a sizeable program in addition to micro-PROLOG and APES.

The plumbing example used in Paragraph 22 made use of another program, called MITSI, which is provided with micro-PROLOG to give a simple form of the language for beginners. APES was used for the medical example and the British Nationality Act example referred to in Appendix C.

As an illustration of how micro-PROLOG and APES work, let us describe the kind of student that we wish to admit to a college of further education. Someone should be admitted if they have applied to the college where they wish to take a course offered by the college, and they can satisfy the entry requirements for the course. Using the computer we can type:

```
x should-be-admitted-to  college if
        x       has-applied-to college   and
        x       wishes-to-study  y       and
        y       offered-by college       and
        x       can-meet-entry-requirements-for y
```

Although our program has no knowledge of any particular applicant or of the college, it can be used to help the admissions problem. Let us find if John should be admitted, and start with the question.

```
confirm (John should-be-admitted-to college)
```

In the exchange that follows, the responses from the computer are shown in bold type

```
Is it true John has-applied to college?
yes
which (x: John wishes-to-study x)
answer is Electricial-Engineering
answer is Mathematics
answer is end
Is it true that Electrical-Engineering offered-by
college?
yes
Is it true that John can-meet-entry-requirements-
for Electrical-Engineering?
why?
If John can-meet-entry-requirements-for Electrical-
Engineering then John should-be-admitted-to
college
Is it true that John can-meet-entry-requirements-
for Electrical Engineering?
yes
Yes, I can confirm that
      John should-be-admitted-to college
how?
To deduce that
      John should-be-admitted-to college
I used the rule
```

x should-be-admitted-to college if

x	has-applied-to college	and
x	wishes-to-study y	and
y	offered-by college	and
x	can-meet-entry-requirements-for	y

I can show that

1. John has-applied to college
2. John wishes-to-study Electrical-Engineering
3. Electrical-Engineering offered-by college
4. John can-meet-entry-requirements-for Electrical-Engineering

As extensions to this simple exchange we could envisage a database of courses offered by the college which could be checked, and rules to determine whether John met the necessary entry requirements, taking into account his background, qualifications and experience. At the end of a dialogue the computer has learnt new information concerning the problem. The inverview may decide to refine his admission procedure, and amend the program accordingly.

APPENDIX D
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APPENDIX E

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Objectives

The objects for which **The Further Education Unit (FEU)** is established are to promote, encourage and develop the efficient provision of further education in the United Kingdom and for that purpose

a) to review and evaluate the range of existing further education curricula and programmes and to identify overlap, duplication, deficiences and inconsistencies therein,

b) to determine priorities for action to improve the provision of further education and to make recommendations as to how such improvements can be effected,

c) to carry out studies in further education and to support investigations of and experimentation in, and the development of further education curricula and to contribute to and assist in the evaluation of initiatives in further education,

d) to disseminate and publish information and to assist in the dissemination and publication of information about recommendations for and experiments and developments in further education.

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